Exhibit A

Expert Report
of
James T. Wells, PhD, PG

L. Everett & Associates, LLC

In the matter of:

McClurg, et al.

v.

Mallinckrodt, Inc., et al.

March 31, 2019

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I declare under penalty of perjury that the following is true and correct, to the best of my information and belief. Executed on March 31, 2019 at Santa Barbara, California.

James Wells

James T. Wells, PhD, PG
L. Everett & Associates, LLC

Section 1. Introduction and Methodology

I have been retained by Humphrey, Farrington & McClain on behalf of certain plaintiffs in this case to provide scientific input and expert opinions concerning the nature and extent of contamination on and around the St. Louis Airport Storage Site (SLAPS), the Hazelwood Interim Storage Site (HISS; also known as the Latty Avenue Site) and properties in the vicinity of these sites, including Coldwater Creek: all in Missouri. I have also been asked to evaluate the fate and transport mechanisms that led contamination to spread into the vicinity areas. In particular, for this report, I have been asked to provide opinions and analysis related to certain information requirements specified in Case Management Order No. 14 for Future Consolidated Cases Filed Against Cotter Corporation (NSL) and/or Mallinckrodt LLC, dated October 15, 2018.

In this report, I have described my opinions and the bases for these opinions. In arriving at the opinions expressed in this report, I have relied upon my education and more than 25 years of experience in environmental science, hydrogeology and mechanisms of contaminant migration, including the groundwater, surface water and wind-borne transport which are key areas of impact in this case. I have also relied upon my review of the types of data and documents commonly relied upon by experts in the field. The documents relied upon include those cited in this Report and were reviewed by myself or other staff at L. Everett & Associates, under my direction. I have reviewed thousands of pages of documents made available by the US Army Corps of Engineers (USACE), Atomic Energy Commission (AEC), Nuclear Regulatory Commission (NRC), the potentially responsible parties and their consultants, as well as law firms involved in in this case. Further, I have relied upon reference texts commonly accepted and held reliable by experts in the fields of environmental science, hydrogeology and contaminant fate and transport, as well as generally-accepted principles in those fields. I have considered multiple lines of evidence in my approach as is accepted environmental practice and have also considered alternative theories and explanations in arriving at these conclusions.

If additional relevant information becomes available, I reserve the right to revise these opinions. I may also provide supplemental opinions regarding this case, if requested. In addition to the exhibits included herein, figures, tables and maps included in references cited in this report may be used as trial exhibits. The documents and data considered in preparation of this report are cited in the text and referenced in

footnotes. The opinions described in this report are made to a reasonable degree of scientific certainty and were arrived at using the same methodology I employ in non-litigation projects.

Background and Qualifications for James T. Wells

Currently, I am Principal Geologist and Chief Operating Officer for L. Everett & Associates, LLC, an environmental hydrogeology and remediation company. I am a Professional Geologist (CA PG #7212), licensed by the California Board for Engineers, Land Surveyors and Geologists. I received a PhD in Geological Sciences from the University of Washington in 1990. I received a Master's of Science Degree in Geological Sciences from the University of Washington in 1986. I received a Bachelor's Degree in Earth Sciences from Dartmouth College in 1981. I have personal knowledge of the matters stated herein. If called as a witness, I could and would competently testify to the matters set forth in this report.

I have 25 years of professional experience as an environmental geologist. During the course of my career, I have evaluated soil, soil vapor and groundwater at dozens of sites around the country. My professional work experience includes conducting subsurface investigations to define the nature and extent of contamination in soil, air and groundwater, contaminant fate and transport modeling, and evaluating remediation strategies.

I am a member of the Editorial Board of the journal, Environmental Forensics, a quarterly peer-reviewed scientific journal of national and international circulation. In this role, I evaluate the work of others through peer-review of manuscripts submitted for publication to the journal. I also participate in publication decisions, as well as establishing and maintaining the editorial direction of the journal. I am the author and coauthor of scientific publications, including forensic review articles in Environmental Science & Technology (U.K. Edition) Special Issue dedicated to Environmental Forensics.

I was appointed by the State of California Department of Toxic Substances Control and South Coast Air Quality Management District to serve as the Technical Advisor to the Exide Community Advisory Group. In this capacity, I serve as technical liaison between community stakeholders and state regulators for this project involving evaluation and cleanup of up to 10,000 homes impacted by lead emissions from a secondary lead smelter. I have provided expert testimony on this case before a legislative hearing at the state capitol in Sacramento. Considering that the principal transport mechanism at Exide was airborne emissions and dust migration in air, this case shares technical similarities with West Lake Landfill.

For reviewing data and preparing this report, L. Everett & Associates invoices my time at the rate of $275/hr. My hourly rate for deposition and trial testimony is $500/hr. A complete copy of my resume is

provided as Appendix A of this report. I have given expert testimony within the last four years, in deposition or trial, as set forth in my resume.

Summary of Opinions

This is a case about releases of radiological compounds and metals from the St. Louis Airport Storage Site (SLAPS), the Hazelwood Interim Storage Site (also known as the Latty Avenue Site) and haul roads to and from these properties. Over the years, radiological and metal constituents have migrated from these sites by a variety of transport pathways, leading to the contamination of surrounding properties. These so-called "Vicinity Properties" include Coldwater Creek, which runs near the SLAPS and Latty Avenue Sites and then continues through an area that has grown into densely developed suburbs of St. Louis, before discharging to the Missouri River. Over many years, some of the contamination from SLAPS and Latty Avenue has migrated into Coldwater Creek, as well as onto other neighboring properties. Previous studies and modeling predictions have shown that transport by windblown dust, transport of radon gas in air, surface water runoff, sediment transport and groundwater flow are all proven pathways for contamination to escape into the environment. This report is focused on a specific aspect of the overall fate and transport process: determining the concentrations of effluent discharges at the boundary of the SLAPS and Latty Avenue sites allegedly attributable to Mallinckrodt's and/or Cotter's operations and whether such concentrations exceed the effluent limitations found in applicable historical federal regulations. My opinions for this stage of the case are as follows. Details and the bases for these opinions are provided in Section 2 of this report.

The SLAPS and Latty Avenue Sites were contaminated with radiological materials and metals and the contamination persisted even after the waste piles were removed (Opinion 1). As recognized components of FUSRAP (Formerly Utilized Sites Remedial Action Program), administered by US Army Copy of Engineers, these sites were clearly contaminated. The mission of FUSRAP is to clean up legacy radiological contamination generated by activities of the Manhattan Project which developed atomic weapons in the 1940s and 1950s. Since much of the on-site radioactive material was stored in open waste piles, exposed to rain and wind, **contamination, including radiological materials and metals, has escaped from the SLAPS and Latty Avenue sites and impacted neighboring properties by a number of migration pathways (Opinion 2).** Over the years, contamination has spread in the air as windblown dust and radon, via runoff of surface water and surface water sediments, groundwater flow and resuspension from roads.

Past offsite effluent concentrations in air, water and sediment can be estimated at the boundaries of SLAPS and Latty Avenue using existing data and modeling (Opinion 3). Past concentrations at the property boundary are largely dependent on the source concentrations (i.e., the average contaminant

concentrations of the various waste products that were exposed to the elements at these sites) and reconstructions of the fate and transport mechanisms that led to mobilization of the contaminants. On-site and offsite sampling of the soil, water and air can be used to validate these estimates.

Section 2. Expert Opinions

Opinion 1. The SLAPS and Latty Avenue Sites were contaminated with radiological materials and metals and the contamination persisted even after the waste piles were removed

The 2005 Record of Decision identifies the following compounds as contaminants of concern (COCs)[1]:

Radionuclides	Metals
Radium-226	Antimony
Radium -228	Arsenic
Thorium-228	Barium
Thorium-230	Cadmium
Thorium-232	Chromium
Uranium-234	Molybdenum
Uranium-235	Nickel
Uranium-238	Selenium
Lead-210	Thallium
Protactinium-231	Uranium
Actinium-227	Vanadium

St. Louis Airport Site

During World War II, Mallinckrodt Chemical Works in downtown St. Louis (under FUSRAP, this facility is now known as the St. Louis Downtown Site or "SLDS" which was also highly contaminated) played a role in what we now know as the Manhattan Project to purify uranium for the first nuclear weapons. Uranium processing at Mallinckrodt continued until about 1957. In 1946, the Manhattan Engineer District acquired the 21.7-acre tract of land (now known as SLAPS) north of the St. Louis Airport to store radioactive residues from uranium processing at Mallinckrodt's downtown facility (see Exhibit 1). These wastes were essentially mine tailings. Wastes (also sometimes referred to as "raffinates") from different stages of the refinement process had different chemical and radiological characteristics and when stored at SLAPS (and later at Latty Avenue) the different wastes were generally kept separate from one another. These materials included pitchblende raffinate residues, radium-bearing residues, barium sulfate cake,

[1] USACE, 2005, Record of Decision for the North St. Louis County Sites, Table 2-2.

Colorado raffinate residues, and contaminated scrap. Some of the residues were stored in bulk on open ground. Others were stored in drums that were stacked across the site.[2]

In 1966 and 1967, most of the stored residues were sold to a private entity for recycling and were removed from SLAPS (much of this material was moved temporarily to Latty Avenue which is also known as HISS or the Hazelwood Interim Storage Site in FUSRAP parlance). On-site structures at SLAPS were razed and demolition debris was buried on the property. Although these activities reduced the surface dose rate to levels acceptable at the time, buried deposits of uranium-238, radium-226 and thorium-230 remained on the property.

In 1973, the tract was transferred from the Atomic Energy Commission (AEC) to the City of St. Louis. US Congress passed a bill in 1984 allowing DOE to reacquire the property from the city for use as a permanent disposal site for the wastes already on the property, contaminated soil in the surrounding ditches and the waste from the nearby Latty Avenue Site. DOE ultimately declined to take back the SLAPS property from the city until a more thorough environmental review was conducted.

Starting in about 1976, Oak Ridge National Lab (ORNL) and its contractors conducted radiological investigations at SLAPS.[3] This work found offsite contamination in the form of elevated concentrations of uranium-238 and radium-226 in drainage ditches north and south of McDonnell Boulevard. In 1981, the drainage ditches were designated for remedial action under FUSRAP. In October 1989, the EPA designated SLAPS as part of the St. Louis Airport/Hazelwood Interim Storage/Futura Coatings, St. Louis, MO Superfund site under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). USACE refers to these sites (plus the so-called "Vicinity Properties") as the North St. Louis County sites.[4]

In 1997, Congress transferred responsibility of FUSRAP to the US Army Corps of Engineers (USACE) from the Department of Energy. USACE has articulated that the primary goal for cleanup and

[2] Bechtel, 1990, Radiological Characterization Report for FUSRAP Properties in the St. Louis, Missouri Area, Section 1.

[3] ORNL, 1987. Radiological Survey of Properties in the Vicinity of the Former Cotter Site, Hazelwood/Berkeley, Missouri. ORNL, 1985. Results of the Mobile Gamma Scanning Activities in Berkeley, Bridgeton, and Hazelwood, Missouri. Health and Safety Research Division. ORNL, 1986. Results of the Radiation Measurements Taken at Transportation Routes (LM004) in Hazelwood, Missouri. Bechtel, 1983, Radiological Survey Of The Ditches At The St. Louis Airport Storage Site.

[4] USACE, 2005, Record of Decision for the North St. Louis County Sites.

management of SLAPS is to restrict the release of contaminated materials and minimize their potential impact on human health, wildlife and the environment.[5]

In 1997, an interim Engineering Evaluation/Cost Analysis (EE/CA) proposed the removal of radioactive wastes immediately adjacent to Coldwater Creek at the West End of SLAPS and recommended that this material be shipped to a licensed, out-of-state disposal facility.[6] The purpose of this action was to minimize the potential for migration of contaminated material to the creek while the more comprehensive sitewide remediation could be planned and carried out. This removal action resulted in the disposal of 5,100 cubic yards of contaminated material that was nearest to the creek.[7]

USACE also began groundwater studies for SLAPS in the late 1990s by installing groundwater monitoring wells, assessing groundwater flow directions and testing groundwater samples for radiological and chemical contaminants. In 1999, USACE issued another EE/CA proposing measures to stabilize on-site material and soil on the adjacent ballfields until a more comprehensive cleanup could be achieved.[8] This plan called for the excavation of material exceeding radium-226 and thorium-230 concentrations of 5 pCi/g above background in the near-surface soil (top 6 inches as averaged over a 100 square-meter area); and 15 pCi/g above background for deeper soil. Soil with uranium-238 in excess of 50 pCi/g above background was also targeted for cleanup. At this time USACE also made efforts to control off-site migration of contamination, including surface water runoff. This included construction of a sedimentation basin on the west end of the site, near Coldwater Creek. Interim remediation work at SLAPS (under the EE/CA) continued until 2005.[9]

A full-scale feasibility study was completed in 2003[10] and subsequently, the Record of Decision (ROD) was issued in 2005 which documented objectives for full-scale remediation of all North St. Louis-area FUSRAP sites.[11] The final remedy consisted of excavation to achieve remediation goals for near-surface soils, subsurface soils and stream sediment in and around Coldwater Creek. Overall, more than 600,000 cubic yards of radiologically contaminated material was removed from SLAPS.[12] For context, a typical

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[5] USACE, 2003, Proposed Plan for the North St. Louis County Sites, p. 2.

[6] DOE, September 1997, St. Louis Airport Site (SLAPS) Interim Action Engineering Evaluation/Cost Analysis (EE/CA) St. Louis, Missouri, DOE/OR-21950-1026.

[7] USACE, 2005, Record of Decision for the North St. Louis County Sites, p. 2-6.

[8] USACE, 1998, Engineering Evaluation/Cost Analysis (EE/CA) and Responsiveness Summary for the St. Louis Airport Site (SLAPS) and Action Memorandum.

[9] USACE FUSRAP website: https://www.mvs.usace.army.mil/Missions/FUSRAP/SLAPS.aspx, accessed on March 19, 2019.

[10] USACE, May 2003, Feasibility Study For The St. Louis North County Site.

[11] USACE, 2005, Record of Decision for the North St. Louis County Sites.

[12] USACE FUSRAP website: https://www.mvs.usace.army.mil/Missions/FUSRAP/SLAPS.aspx,

load for a dump truck is about 15 cubic yards, so more than 40,000 dump truck loads of radioactive material was removed from the SLAPS site over the years. USACE still conducts site monitoring at SLAPS which is documented in annual monitoring reports.[13]

For Superfund sites that leave contamination on-site or that continue for many years, five-year reviews are conducted, as mandated by CERCLA. The purpose of a five-year review is to evaluate the implementation and performance of a remedy to determine if the remedy is or will be protective of human health and the environment.[14] Thus far, Five-Year Review Reports have been issued in 2004, 2010 and 2015.[15]

Latty Avenue Site

In 1966, uranium processing wastes from the Mallinckrodt Chemical Works that had been stored at SLAPS were purchased by the Continental Mining and Milling Company and moved to a storage site on Latty Avenue (see Exhibit 1).[16] Wastes included in this transfer included 74,000 tons of Belgian Congo pitchblende raffinate containing approximately 13 tons of uranium; 32,500 tons of Colorado raffinate containing roughly 48 tons of uranium; and 8,700 tons of leached barium sulfate containing about 7 tons of uranium. Some of the material was then dried and shipped to Cotter Corporation's ore processing mill in Canon City, Colorado. The material remaining at the Latty Avenue storage site was sold to Cotter Corporation in 1969 and shipments to Canon City continued through 1970. However, because it could not be economically processed for reclamation, the 8,700 tons of leached barium sulfate (and some other wastes), remained at Latty Avenue. In 1973, this remaining uranium processing waste was mixed with approximately 39,000 tons of soil from Latty Avenue and transported offsite. In 1974, the AEC noted that Cotter's disposition of the leached barium sulfate waste from Latty Avenue was improper: "The disposal does not appear to be within the intent of the Commissions' regulation, 10 CFR Part 40, to allow alteration of the physical nature of Source material (i.e. dilution of solids with nonradioactive source material) in order to obtain a physical mixture which would no longer be subjected to licensing by the Commission."[17]

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accessed on March 19, 2019.

[13] See, for example, USACE, 2018, North St. Louis County Sites Annual Environmental Monitoring Data And Analysis Report For Calendar Year 2017.

[14] EPA, 2001, Comprehensive Five-Year Review Guidance, EPA 540-R-01-007, p. 1-1.

[15] USACE, 2004, Initial Five-Year Review Report for Formerly Utilized Sites Remedial Action Program (FUSRAP) St. Louis Sites, St. Louis, Missouri; USACE, 2010, Second Five-Year Review Report for Formerly Utilized Sites Remedial Action Program (FUSRAP) St. Louis Sites, St. Louis, Missouri; USACE, 2015, Five-Year Review Report Third Five-Year Review Report For Formerly Utilized Sites Remedial Action Program (FUSRAP) St. Louis Sites.

[16] USACE, 2005, Record of Decision for the North St. Louis County Sites, p. 2-3 to 2-4.

[17] AEC, November 1, 1974, Letter to Cotter Corporation, p. 2

Oak Ridge National Labs (ORNL) performed a radiological characterization at Latty Avenue in 1990.[18] Thorium and radium contamination in excess of federal guidelines was found in and around the buildings and in the soil to depths of 18 inches. Subsequently, in preparing the property for use, the owner demolished one building and excavated approximately 13,000 cubic yards of contaminated soil from the western half of the property, which was simply stockpiled on the eastern portion of the property. This began a second phase for Latty Avenue as an interim waste disposal facility: accepting waste from surrounding FUSRAP activities.

An additional 14,000 cubic yards of contaminated soil, from cleanup along Latty Avenue in 1984 and 1985 and from an area used for office trailers and a decontamination pad, was added to the pile. Approximately 4,600 cubic yards of contaminated soil was stored adjacent to the existing pile; the soil had been excavated during road and drainage improvements along Latty Avenue in support of a municipal storm sewer project. A total of 32,000 cubic yards of contaminated soil was stored on the property in the 1980s.[19]

In 1981, Oak Ridge Associated Universities conducted a radiological characterization of the waste pile and surveyed portions of the northern and eastern vicinity properties for radioactivity.[20] Levels of contamination (principally thorium-230) similar to those on the pile were found in both areas. As a follow-up, ORNL conducted offsite radiological surveys of roadways in the vicinity of Latty Avenue;[21] results indicated contamination in excess of federal guidelines along the road beyond Hazelwood Avenue. Properties adjacent to HISS were also found to be contaminated in excess of guidelines. Soon after, Congress added the Latty Avenue properties to FUSRAP in order to expedite decontamination.

In October 1989, the Environmental Protection Agency (EPA) designated a Superfund site in this area that included the HISS/FUTURA properties, thus subsequent cleanup was to proceed under CERCLA guidelines. In 1992, an Engineering Evaluation/Cost Analysis (EE/CA) for the proposed decontamination of HISS and impacted soil from three adjacent Latty properties was published by USACE.[22] The EE/CA

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[18] ORNL, 1990, Radiological Characterization Report for FUSRAP Properties in the St. Louis. Missouri, Area.

[19] USACE FUSRAP website: https://www.mvs.usace.army.mil/Missions/FUSRAP/HISS/, accessed March, 20, 2019.

[20] Oak Ridge Associated Universities, 1981, Radiological Evaluation of Decontamination Debris Located at the Futura Chemical Co. Facility in Hazelwood, MO.

[21] ORNL, 1991, Results of Mobile Gamma Scanning Activities in St. Louis, Missouri; ORNL, 1986, Results of the Radiation Measurements Taken at Transportation Routes in Hazelwood, Missouri; ORNL, 1985, Results of the Mobile Gamma Scanning Activities in Berkeley, Bridgeton, and Hazelwood, Missouri.

[22] USACE, 1992, Engineering Evaluation/Cost Analysis-Environmental Assessment for the Proposed Decontamination of Properties in the Vicinity of the Hazelwood Interim Storage Site Hazelwood, Missouri.

called for any contaminated soil excavated from the site to be shipped to an appropriately-licensed out-of-state disposal facility.

In 1996, the owner of 9150 Latty Avenue, located to the east of HISS, expanded their facility and stockpiled about 8,000 cubic yards of contaminated soil. This stockpile, known as the Eastern Pile, was located on the southwestern corner of the property.

In March 1998, USACE prepared an EE/CA proposing to remove the waste piles and impacted soil from three adjacent Latty Avenue properties until a comprehensive cleanup could be achieved.[23] USACE started waste and soil removal in spring 2000 and completed this work in 2001. Over 52,000 cubic yards of contaminated material was removed and transported for disposal at an out-of-state disposal facility.

The subsequent 2005 ROD addressed this site as well as SLAPS and the SLAPS Vicinity Properties.[24] The final remedy consisted of excavation to achieve remediation goals for near-surface soils, subsurface soils and stream sediment in and around Coldwater Creek. From 2010-2013, USACE largely focused on characterizing and cleaning up the 148 Vicinity Properties that had been identified as containing or potentially containing contamination that had migrated from SLAPS, Latty Avenue and/or historical haul roads.[25]

Opinion 2. Contamination including radiological materials and metals has escaped from the landfill and impacted neighboring properties by a number of migration pathways

There are a number of physical fate and transport processes that contributed to the release of contamination from SLAPS and Latty Avenue, impacting Coldwater Creek and other properties. Over the years, contamination has spread via runoff of contaminated surface water and surface water sediments, in the air as windblown dust and radon and via groundwater flow. In addition, contamination was released to the environment via spillage along haul roads to and from SLAPS and Latty Avenue. This roadside contamination was also subject to resuspension and redistribution to locations more distant from the roadways by traffic and wind. In accordance with the Scheduling Order, contaminant transport by surface water runoff, airborne particulates and radon in air are addressed in this report. I reserve the right to address other transport mechanisms in the future, which were also contributors to offsite exposure of radionuclides and metals from these facilities. Of particular note, researchers have concluded that an important exposure pathway at this site is transport and redistribution of contaminated sediments down

[23] USACE, 1998, Engineering Evaluation/Cost Analysis (EE/CA) for the Hazelwood Interim Storage Site (HISS).

[24] USACE, 2005, Record of Decision for the North St. Louis County Sites.

[25] USACE, 2015, Five-Year Review Report Third Five-Year Review Report For Formerly Utilized Sites Remedial Action Program (FUSRAP) St. Louis Sites.

Coldwater Creek and its floodplain (especially during flood events which had the potential to deposit contaminated sediments directly into the yards of residential properties that abut the creek).[26] The scheduling order does not ask about the sediment transport exposure pathway so it is not addressed in this report, but will likely be important as the case proceeds. For example, in the 2003 Feasibility Study, USACE describes sediment contamination as follows:

> "Concentrations of Th-230 in sediment ranged from 0.2 to 1400 pCi/g, with the corresponding concentrations of U-238, and Ra-226 ranging from background to 10.9, and background to 25.1, respectively. Sediment with elevated levels of radioactive material is intermittently located in creek bends where natural settling would occur. Contamination levels are highest near SLAPS and HISS, but decrease greatly downstream."[27]

Mallinckrodt and Cotter would have been aware of this issue because AEC had observed and reported uncontrolled releases of contaminated sediment at least by 1948. In a report by entitled, "Uranium Contamination at Airport Storage Area, St. Louis, Missouri, AEC identified "mud samples" adjacent to what is now known as the SLAPS site with uranium concentrations 190 times that of the normal uranium content in soil.[28] Again, I limit my opinions in accordance with the Scheduling Order to contaminant transport by surface water runoff, airborne particulates and radon in air. But what is clear from my initial review, including the inspection reports, is that there were serious violations of regulations at both sites. In fact, both Mallinckrodt and Cotter engaged in a pattern and practice of failing to act with appropriate care, directly leading to releases of contamination in excess of federal limits. I reserve the right to address these matters in the future.

Another transport pathway is purposeful removal of waste or contaminated soil from SLAPS for use as fill at neighboring sites. I do not know how prevalent this practice was, but there is a troubling record of contaminated soil apparently being used to build a ramp to a parking garage at the St. Louis Airport.[29] To my knowledge, there has never been a serious investigation into whether AEC, Mallinckrodt and/or Cotter allowed other entities to remove wastes from SLAPS or Latty Avenue for use as fill in construction projects.

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[26] SAIC, 1993b. Evaluation of Contaminated Sediment Transport in Coldwater Creek, St. Louis, Missouri; USACE, 2003, Feasibility Study for the St. Louis North County Site.

[27] USACE, 2003, Feasibility Study for the St. Louis North County Site, p. 2-59.

[28] AEC, November 1, 1948, Uranium Contamination at Airport Storage Area, St. Louis, Missouri, p. 2.

[29] DOE, January 20, 1989, Letter to St. Louis Airport Authority re: Contaminated Soil Beneath Parking Garage Ramp.

Opinion 3. Past offsite effluent concentrations air, water and sediment can be estimated at the boundaries of SLAPS and Latty Avenue using existing data and modeling

The Case Management Order requires plaintiffs to determine the concentrations of effluent discharges at the boundary of the SLAPS and Latty Avenue sites allegedly attributable to Mallinckrodt's and/or Cotter's operations and whether such concentrations exceed the effluent limitations found in applicable federal regulations: 10 CFR §20.106(a), Appendix B. Important dates are as follows:

- Waste from Mallinckrodt's downtown processing facility was transported to SLAPS starting in 1946.
- Mallinckrodt managed the SLAPS site from 1953 to early 1966.
- Certain wastes were transferred from SLAPS to HISS in the second half of 1966
- Cotter signed a purchase agreement with CDC for residues in 1967.
- Cotter purchased remaining residues in 1969.
- Last waste material was removed from HISS in 1973.

Briefly, it is my opinion that effluent limitations for water may not have been exceeded[30] but effluent limitations for air were exceeded at both SLAPS and Latty Avenue. The scientific rationale for these findings is supplied below and specific concentration estimates are provided in the tables accompanying this report.

The effluent limitations in 10 CFR §20 have been revised by the NRC a number of times over the years; it is my understanding that the Order envisions comparing site discharges to the original effluent guidelines promulgated in 1960. These original tables include different limits for "soluble" and "insoluble" forms of each radionuclide. The regulations do not provide a definition for these terms; however, the original source of these effluent limitations can be traced to a 1959 Commerce Department publication entitled, "Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and in Water for Occupational Exposure." In this document, the authors explain that the terms "soluble" and insoluble" refer to the behavior of substances in the body: a concept we would now call "bioavailability." In its 1979 radiological survey of the SLAPS site, DOE used the "soluble" effluent limitations as a comparative guide, which I believe are the appropriate standards to use for the purpose of this report.[31]

It is noteworthy that the 1959 study upon which the relevant effluent guidelines were based addresses occupational exposure, but NRC subsequently applied these values to "concentrations in effluents to

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[30] Again, this is not to say either Mallinckrodt or Cotter is not strictly liable, did not breach its duty of care, and did not release radiation in excess of federal dose limits. Rather, I am limiting this report to what the Scheduling Order requires and reserve the right to expand on these matters in the future.

[31] DOE, 1979, Radiological Survey of the St. Louis Airport Site, Table 19.

unrestricted areas" which certainly could include residential exposure scenarios. This is probably one reason that the actual cleanup goals established under FUSRAP are different than the published 10 CFR §20 effluent limitations.[32]

Water Releases from SLAPS and Latty Avenue

I am not aware of any comprehensive surface water sampling from either the SLAPS site or Latty Avenue prior to removal of the waste piles. Contaminant concentrations from samples collected after the wastes had been removed and after various phases of remediation are expected to be substantially lower than would have prevailed when the unprotected waste piles remained at these sites, fully exposed to rain events. AEC tested surface water near SLAPS and in Coldwater Creek in 1948, although the only reported analyte is total uranium. At that time, the maximum concentration of uranium in surface water was 7.0 ug/ml (Sample 6, described as "10 ft. from area main stream leading into Cold Water Creek")[33]. This measurement corresponds to 7,000 ug/L which vastly exceeds the current drinking water standard for uranium of 30 ug/L; however, this was a mass analysis, not a radiological activity analysis and uranium (in units of total mass) is not included in the 10 CFR §20 effluent limitation table. The 1948 study also showed a trend of decreasing uranium in surface water and soil in Coldwater Creek with respect to distance downstream from SLAPS. These findings are indicative of very significant releases of radiological contamination into surface water and stream sediments during the time waste piles were present at this site. AEC recognized at the time that the 1948 findings represented releases to the environment from SLAPS: "The results of the mud analysis showed conclusively that some residue from the area had been washed westward towards the creek." (AEC, 1948, p. 2)

Mallinckrodt and Cotter are reasonably sophisticated entities; thus, they were fully capable of collecting comprehensive water samples, but nonetheless chose not to. They are now being rewarded for their inaction because this kind of data cannot be readily reconstructed from currently available information. In addition, considering that AEC knew by 1948 that contamination had spread offsite from the SLAPS site, it is reasonable to assume that Mallinckrodt and Cotter should also have known this fact when they were active at their respective sites. Both sites are within the watershed of Coldwater Creek and runoff from both sites would impact the same reach of the creek, immediately north of the airport. Thus, in my opinion, the data included on Table 1 is reasonably representative of water concentrations from both sites that prevailed after the waste piles were removed but before the FUSRAP remedial actions had been

[32] It is also noteworthy that the 2005 Record of Decision provides cleanup goals for shallow soil, deep soil, sediment and permanent structures, but does not provide cleanup goals for air or water. This is because prior risk assessment had identified exposure to soil and sediment as the dominant source of risk.

[33] AEC, November 1, 1948, Uranium Contamination at Airport Storage Area, St. Louis, Missouri, Table entitled, "Analyses of Water Samples Taken at Airport Area & Cold Water Creek."

completed. I am sure that water concentrations would have been higher when the waste piles were present, but there are not sufficient data available to me at this time to reconstruct how much higher the concentrations would have been earlier in the history of these sites. As shown in Table 1, the maximum measured radiological concentrations are less than the 10 CFR §20 effluent limitations for water. Table 1 also provides the necessary unit conversions for the regulatory effluent limitations to match the units used in site-specific sampling data. One issue that remains unresolved at this time is whether historical runoff from these sites would have contained enough particulate contamination entrained within the water as total suspended solids such that the sum of dissolved and suspended contamination would exceed the 10 CFR §20 effluent limitations. At this stage in my analysis, I cannot affirm that the combined contaminant levels would have exceeded the effluent limitations, but I reserve the right to conduct additional analysis on this issue if or when more relevant data become available to me.

Radon Releases from SLAPS

Radon concentrations at or near the fence line of the SLAPS site were measured at levels up to 210 pCi/L in 1948.[34] The appropriate 10 CFR §20 effluent limitation for radon-222 in air is 3 x 10^{-9} uCi/ml. Applying unit conversions, this corresponds to 3.0 pCi/L, thus the concentration of radon at the boundary of the SLAPS site was up to 70 times higher than the 10 CFR §20 effluent limitation for air during the period of time that the waste material was stored at the site. This finding is perhaps not surprising considering that onsite measurements in 1948 had found radon at concentrations up to 2,440 pCi/L.[35] Although material was progressively removed from the site starting in the 1950s, a large volume of waste remained at SLAPS until it was transferred to HISS in 1966. For this reason, I believe the 1948 radon measurements are broadly representative of emissions from SLAPS through 1966.

Radon Releases from Latty Avenue

It is possible to estimate the concentration in air at some specified point (in this case, the Latty Avenue fence line) using the expression DF = χ/Q where:

DF = Dispersion Factor;

χ = Concentration in air at a given point; and

Q = release rate.

Risk Assessment Corporation reports a release rate of 1.2 x 10^{-4} Ci/s for Latty Avenue (RAC, 2018, p. 4-35); a perimeter dispersion factor of 6.21 x 10^{-5} s/m^3 (RAC, 2018, p. 4-32); and an average on-site radon concentration of 168 pCi/L (RAC, 2018, p. 4-35). Solving for concentration at the fence line, we arrive at

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[34] AEC, 1948, Radon Samples Taken in Airport Area, Robertson, Missouri. (author: P.B. Klevin); RAC, 2018, Reconstruction of Plaintiff Doses Associated with Residues Stored at the St. Louis Airport Storage Site and the Hazelwood Interim Storage Site and Critique of Opinions by Dr. Cheremisinoff, Ms. Sears and Dr. Clark, p. 5-12.

[35] AEC, 1948, Radon Samples Taken in Airport Area, Robertson, Missouri. (author: P.B. Klevin).

an estimated radon concentration of 7,450 pCi/m^3, or 7.45 pCi/L which is valid for the period of time that the waste material was stored at this site. This value exceeds 10 CFR §20 effluent limitation of 3.0 pCi/L for radon in air. After the wastes had been removed, measured radon concentrations were much lower at both sites and concentrations likely declined even further after completion of FUSRAP soil remediation. For example, in the 1990s, radon concentrations at the Latty Avenue fence line were up to approximately 0.6 pCi/L and in 2015, SLAPS outdoor radon concentrations were between non-detect and 0.4 pCi/L.[36]

Air Releases from SLAPS

Both sampling and modeling have shown that airborne transport of contaminated particulates is another pathway for offsite migration at these sites. [CITATIONS] With respect to windblown dust, we need three principal inputs to estimate past exposures: 1) Source area waste or soil concentrations; 2) average concentration of total suspended particulates (i.e., dust) from the sites; 3) mixing or dilution factors between source and receptors. In order to comply with the Scheduling Order in this case, the "receptor" may be set to the fence lines of SLAPS and Latty Avenue. Source area waste/soil concentrations for SLAPS are given by RAC, 2018 as follows:

Mean Radionuclide Concentrations in SLAPS Residues[37]

Source:	Congo raffinate (AM-7+AM-9)	Colorado raffinate (AM-10)	Barium sulfate (AJ-4)[a]	Interim residue plant tailings	C-liner slag	*Weighted Average*
			pCi/g			
^{238}U	5.1×10^{2}	5.2×10^{2}	1.3×10^{3}	6.5×10^{3}	5.0×10^{3}	1.2×10^{3}
^{230}Th	4.7×10^{4}	4.8×10^{4}	1.6×10^{5}	5.7×10^{1}	2.3×10^{2}	5.1×10^{4}
^{226}Ra	3.5×10^{2}	5.7×10^{2}	2.6×10^{3}	5.7×10^{1}	2.3×10^{2}	5.5×10^{2}
^{210}Pb[b]	3.5×10^{2}	5.7×10^{2}	2.6×10^{3}	5.7×10^{1}	2.3×10^{2}	5.5×10^{2}
^{232}Th	3.3×10^{0}	7.7×10^{0}	6.3×10^{1}	6.3×10^{1}	6.3×10^{1}	1.6×10^{1}
^{234}U[c]	5.1×10^{2}	5.2×10^{2}	1.3×10^{3}	6.5×10^{3}	5.0×10^{3}	1.2×10^{3}
^{228}Ra[d]	9.3×10^{-1}	2.1×10^{0}	1.8×10^{1}	1.8×10^{1}	1.8×10^{1}	4.4×10^{0}
^{228}Th[d]	2.8×10^{0}	6.5×10^{0}	5.4×10^{1}	5.4×10^{1}	5.4×10^{1}	1.3×10^{1}
^{235}U[e]	2.5×10^{1}	2.5×10^{1}	6.2×10^{1}	3.1×10^{2}	2.4×10^{2}	5.6×10^{1}
^{231}Pa[f]	2.8×10^{3}	3.6×10^{2}	1.2×10^{3}	4.3×10^{-1}	1.7×10^{0}	1.7×10^{3}
^{227}Ac[f]	2.8×10^{3}	6.8×10^{2}	2.4×10^{3}	8.2×10^{-1}	3.3×10^{0}	1.9×10^{3}

[36] USACE, 2016, North St. Louis County Sites Annual Environmental Monitoring Dat and Analysis Report for Calendar Year 2015, Table 2.5.

[37] Source of Table: RAC Expert Report, 2018, Tables 4-6 and 4-7.

Notes for Table

a. Uses a weighted mean based on relative amounts of leached and unleached material.
b. Assumed to be in secular equilibrium with ^{226}Ra.
c. Assumed to be in secular equilibrium with ^{238}U.
d. $^{228}Ra = 0.28 \times ^{232}Th$; $^{228}Th = 0.85 \times ^{232}Th$ based on Table 4-2 in 1998 NESHAP report in USACE Environmental Monitoring Report for 1998.

e. Natural activity fraction of ^{238}U ($^{235}U = 0.0484 \times ^{238}U$).

f. Except for AM-7, $^{231}Pa = ^{230}Th/133.3$ and $^{227}Ac = ^{230}Th/69.8$. These ratios were derived from soil data (see section 5). For AM-7, ^{231}Pa concentrations are based on reported activity concentrations (Haubach 1970; Cotter Corporation 1986) and ^{227}Ac is assumed to be in secular equilibrium with ^{231}Pa.

The airborne concentration of radionuclides can be derived from a measurement of total uranium in air in which was collected in 1960 as part of Mallinckrodt's annual monitoring program.[38] Four samples were collected near the SLAPS property line and the highest concentration of uranium detected reported as 4.5 x 10^{-14} uc/cc. Using natural abundances of the three isotopes of uranium, this finding can be speciated as follows:

Speciation of 1960 data among uranium isotopes using natural abundances

	Mass Fraction in Nature	Specific Activity	Mass-weighted Activity	Activity Ratio	1960 Total U	Speciation of 1960 data	pCi/cm^3	pCi/m^3
Total U					4.50E-14			
^{238}U	99.27%	3.36E+05	3.34E+05	48.3%		2.17E-14	2.17E-08	2.17E-02
^{235}U	0.72%	2.16E+06	1.56E+04	2.2%		1.01E-15	1.01E-09	1.01E-03
^{234}U	0.0055%	6.22E+09	3.42E+05	49.5%		2.23E-14	2.23E-08	2.23E-02

Having determined the activity of uranium-238, the concentrations of other alpha-emitting radionuclides of concern can now be estimated from their respective activity fractions as tabulated by Risk Assessment Corporation.[39] The concentrations are presented in Table 2. In my expert opinion, these values are one reliable example of air concentrations at the fence line of the SLAPS site during the period of time that waste piles were present. It is noted that thorium-230 exceeds its 10 CFR effluent limitation for air.

The concentrations presented in Table 2 are representative of conditions on the day of sampling in 1960 but, in my opinion, they should not be construed as representing maximum air concentrations historically released from the SLAPS site. This is an important issue because dust storms from the land surface are

[38] Annual Off-Site Environmental Monitoring Report, MLCT_TParty_0000515
[39] RAC, 2018, Table 4-16.

episodic events in which the vast majority of dust generation occurs only during those days or portions of a day each year with high winds. Typically, modeling studies develop daily average concentrations, which are valid across an entire year, but are not accurate for windy days. However, it is important to remember that most days, winds are mild and will have very little dust generation. As such, sampling conducted on a calm day, would greatly underestimate "average" airborne concentrations. On windy days, the concentrations were likely far in excess to the values presented in Table 2. There is no documentation that Mallinckrodt made any effort to collect air samples on windy days.

Air Releases from Latty Avenue

Radioactive material that was released to the atmosphere at Latty Avenue as a result of a waste drying operation. The raffinate materials at Latty Avenue had relatively high moisture contents. To reduce shipping costs, operators at Latty Avenue decided to remove moisture from the wastes before they were shipped by rail for reprocessing. Drying was accomplished by a rotary dryer that was installed inside a building at HISS. A scraper would collect the wet residue and load it onto a conveyor belt (AEC 1968). Material then entered a large inclined rotating cylinder, and as it progressed down the cylinder, air was blown across with waste with a powerful blower. This process reportedly dried the waste from a moisture content of approximately 45-48% to as low as 18% (Goff, 1969b). When the material reached the lower end of the rotating cylinder, it was loaded into open-top railroad cars for transport to Cañon City, Colorado (AEC 1968).

RAC has studied the atmospheric release implications of the drying operation and has estimated PM10 releases in units of total tons of Congro raffinate (AM-7) and Colorado raffinate (AM-10) for each of the six quarters between 1968 and 1971 when drying was being conducted at Latty Avenue.[40] I have reviewed RAC's calculations and although it must be acknowledged that there is considerable uncertainty in these calculations, they are reasonable estimates of releases to air during drying operations. RAC found that a total of approximately 10.25 tons (equivalent to 20,500 pounds) of radioactive waste was released to air from the drying operations at Latty Avenue. RAC calculated the total curies released from each radionuclide of concern over the entirety of the drying operation (2018, Table 4-34: Total Curies Released from Dryer Operation). These values can be converted to concentrations by dividing by the total amount of air passing across the site each quarter, incorporating the conservative assumption of thorough mixing of the airborne particulates with air passing across the entire site. This calculation is presented below:

[40] RAC, 2018, Table 4-33, PM10 Releases from Dryer Operations. "PM10" stands for particulate matter in air with a diameter of less than 10 microns. These fine particulates are of particular concern in exposure assessments because the are respirable if people are breathing ambient air with particulates of this size or smaller.

Average windspeed (RAC, 2018, p. 7-17)	4.27	m/s
Size of Latty Ave Site	10.46	acres
Size of Latty Ave Site	42,330	m^2
Modeling length (sq root of size)	206	m
Modeling height	10.0	meters
Modeling volume	423,302	m^3
Time for wind to cross the site	48.24	s
Number of air exchanges per hour	74.62	
Number of air exchanges per day	1791	
Number of air exchanges per qtr (120 days)	214,910	
volume of air per quarter	9.10E+10	m^3

As shown on Table 3a, I first calculated total curies released per quarter, per radionuclide. Then in Table 3b, these mass values were converted to concentrations by allocating mass across my estimate of volume of air passing across the site each quarter. This result is equivalent to the average concentrations at the fence line per quarter. It is noted that thorium-230 exceeds the 10 CFR effluent guideline for air in each quarter and proactinium-231 exceeds the effluent guideline for two quarters in 1968.

It is perhaps unsurprising to find some exceedances of effluent guidelines at Latty Avenue because this facility received notices of non-compliance from AEC in 1966 and 1967 for contamination in unrestricted areas. The 1966 notice identified five items of non-compliance, including the finding that "contrary to 10 CFR 20.105, on May 16, 1966, radiation levels existed in the unrestricted areas around the "Barrel storage area" such that an individual could receive a dose in excess of those limits specified in this part." It was also found that uranium residues were being stored at this site prior to completion of fencing and installation of locked gates, thus failing to implement a controlled area for these wastes.

In 1967, the AEC inspector reported that "radiation levels were found emitting from the stockpile area in excess of 1.3 mr/hr at 1 meter from the ground and from the barrel storage area at 10 mr/hr at 18 inches from the barrels. Therefore, contrary to 10 CFR 20.105(b)(2), <u>radiation levels exist in the stockpile area and unrestricted area, such that an individual continuously present in this area could receive a dose in excess of 100 millirem in any seven days.</u>" (AEC, Inspection Sheet for January 11, 1967 Inspection, emphasis added.)

The inspector also found storage material (i.e., radioactive waste) "banked up against the bottom of the cyclone fence, causing it to sag and be partially flattened." AEC determined that this condition makes for ease of entrance to the controlled areas: "In at least two places around the fence line, it would be simple to hold on to the top of the fence and step over the fence into the licensee's facility from the outside. AEC also noted that the main gate had a large gap which made for "extreme ease in entering into the licensee's controlled areas. Finally, AEC noted that windows of the production building were unlocked and opened, providing easy entrance into the building, and therefore into the controlled area. The inspector summed up the situation, concluding that open windows, collapsed fences and open space under that gate negated the "premise that this is a restricted area." This inspection took place a few months before Cotter Corporation took over the site from Commercial Discount Corp., however, at 1970 inspection report documents that poor housekeeping was a persistent problem at Latty Avenue. As in the previous inspections, the 1970 site visit noted that the perimeter fence was in poor condition and in need of repair.[41] Radiation levels were monitored in various work areas and the inspectors found two locations where 8-hours of exposure would result in an exceedance of AEC limitation of 2.0 mrem/hour. The 1970 inspection also documented uncontrolled release of radioactive material beyond the fence line:

> "along the northeastern edge of the property line a quantity of the Congo raffinate material has washed down and under the fence. This material is covering the truck parking lot of the adjacent industry and is definitely a violation of AEC regulations."[42]

Summary

In summary, radon and thorium-230 are calculated to have exceeded 10 CFR §20 effluent limitations for air at the fence lines of both the SLAPS and Latty Avenue sites. In addition, protactinium-241 was found to exceed its relevant effluent limitation for air at Latty Avenue. I have not been able to reconstruct radionuclide concentrations in water leaving the sites during the times that waste piles were present at the sites, exposed to uncontrolled runoff and erosion from rainfall and/or snowmelt events. Water concentrations after the waste was removed from the sites was found to be below 10 CFR §20 effluent limitations.

Notes on Allocation

The Scheduling Order asks for organ doses attributable to Cotter's operations at Latty Avenue and Mallinckrodt's operations at SLAPS. This requires the plaintiffs to determine what percentage of the offsite contamination that the plaintiffs came into contact at various location was due to Cotter's releases

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[41] Ryckman, Edgerley, Tomlinson and Associates, August 11, 1970, Site Visit Report, Cotter Corporation.

[42] Ryckman, Edgerley, Tomlinson and Associates, August 11, 1970, Site Visit Report, Cotter Corporation, p. 2.

and what percentage was due to Mallinckrodt's releases. For the period of time before wastes were transported to Latty Avenue, SLAPS was responsible for 100% of releases to the environment. Pre-1966 impacts to Latty Avenue and vicinity properties would have been relatively small, but since no waste existed at Latty Avenue during this period, 100% of the contamination that reached these areas during this time period is attributed to SLAPS. Those releases included fugitive dust emissions from disturbance of materials in place at SLAPS and the mass transport of contaminants via sheet wash from rain and flooding events. This period extended from 1946 to 1966.

After wastes had been removed from SLAPS and transported to Latty Avenue, the Latty Avenue site was responsible for 100% of the releases to Coldwater Creek and to the surrounding community. I recognize that there were residuals remaining at SLAPS and in the surrounding community after 1966, but the flux of contamination off-site would have been greatly reduced due to the absence of open waste piles and for the purposes of this analysis, I assume the post-1966 annual release rate was much smaller than the pre-1966 annual release rate and would not alter the general allocation presented here. Certain properties immediately adjacent to each site were impacted dominantly (if not exclusively) by the single adjacent site. For example, the railroad tracks adjacent to HISS were impacted by releases during waste loading operations of the concentrated raffinate. As such, it is a reasonable assumption that 90% of the contamination found on this segment of the railroad tracks is attributable to HISS and 10% is attributed to prior airborne releases from SLAPS that would have blanketed the entire area. Similarly, the ballfields immediately north of SLAPS were impacted exclusively by SLAPS until 1966. In this case, however, when the drying operation was active at Latty Avenue, a substantial amount of contaminated dust was mobilized, some of which would have been deposited on the ballfields. I believe it is reasonable to apportion 10% of the total contaminant load found on the ballfields after 1966 to Latty Avenue and 90% to SLAPS.

For Coldwater Creek, some of the wastes released in any one year are incorporated into streambed and floodplain sediments, thus are stored indefinitely in the stream system. Over the years, the relative contributions to stream sediment contamination from each site is a function of the length of time each site had uncontrolled releases. It is assumed that relative responsibility for haul road releases can also be accounted for in this way. To arrive at a reasonable allocation for Coldwater Creek, I utilized a method which draws upon Gore Factors.

The Gore Factors are widely used parameters for allocating liability at Superfund sites and other cases involving toxic releases. Gore Factors trace their origin to an unadopted amendment proposed by then-Senator Gore to the original Superfund bill. Gore suggested that the following factors could be considered when allocating site costs among PRPs: (1) the ability of the parties to demonstrate that their contribution

to a discharge, release or disposal of a hazardous waste can be distinguished; (2) the amount of hazardous substances involved; (3) the degree of toxicity or hazard of the materials involved; (4) the degree of involvement by parties in the generation, transportation, treatment, storage, or disposal of the substances; (5) the degree of care exercised by the parties with respect to the substances involved; and (6) the degree of cooperation of the parties with government officials to prevent any harm to public health or the environment.

In some cases, allocations are relatively straightforward by applying Gore Factor #1. This allocation method could be used if different PRPs (potentially responsible parties) for a hypothetical site handled and released different chemicals. For example, I am working on a site right now in which benzene is related to releases from a gas station and TCE is related to releases from a nearby factory. In a case like that, it is not difficult to differentiate each PRP's singular impacts to the environment and/or human health. Gore Factor #1 would be very difficult to apply in the Coldwater Creek case because the very same materials were stored at each site (although they were stored at each site at different times) and the very same materials were released into the environment by the same fate and transport mechanisms. Because both sites are within the Coldwater Creek watershed, releases became comingled with the exception of the short stream segment downstream of SLAPS but upstream of HISS. In addition, the mode of storage (mostly unprotected waste piles) was the same and environmental conditions (frequency and duration of rain events, snow melt and wind storms) are identical since the two sites are separated by only a couple city blocks. As noted by Ram, et al., [43] timing (for example, for a facility that had different owners: how long did each owner operate the facility or for a landfill: how long did different PRPs send their wastes to the particular landfill?) is a reasonable proxy for Gore Factor #4.

One can calculate the number of years waste piles were present at either site. [44] Mallinckrodt was responsible for waste at SLAPS from 1946 to mid-1966 for a total of approximately 20.5 years.[45] Mallinckrodt's period of operation constitutes 73% of the time waste piles were present at one or the other of the sites (20.5/28 = 0.732). Similarly, Cotter was responsible for waste at Latty Avenue from

[43] Ram, et al., March 15, 2005, Cleanup Costs at Waste Sites, in: Environmental Science & Technology, 129A-135A.

[44] By my calculation, waste piles were present at *either* SLAPS or Latty Avenue for a total of approximately 28 years. There certainly would have been continuing releases to the environment after the waste piles were removed but before on-site FUSRAP remediation was completed. For the purposes of this allocation analysis, I assume post-waste pile/pre-remediation were a relatively small proportion of total historical releases. In addition, such post-waste pile releases Mallinckrodt would not be allocated to either Mallinckrodt or Cotter.

[45] I understand that Mallinckrodt did not officially operate SLAPS until 1953, but it was always Mallinckrodt's waste being stored at the site, being transported directly from Mallinckrodt's downtown facility. Considering these facts, for the purposes of this analysis, I believe Mallinckrodt had some responsibility for safe handling of the waste from the beginning of operations at SLAPS.

mid-1966 through 1973, for a total of 7.5 years. I understand that Cotter did not hold the license for Latty Avenue until 1969: there was a period in 1966 and early 1967 when Continental Mining and Milling and/or Continental Metals Corporation and/or Commercial Discount Corporation held the license. However, as early as 1967, Cotter Corporation contracted to have this material dried and shipped to them in Colorado.[46] In fact, in 1968 Cotter Corporation referred to this site as "our drying plant in Hazelwood, Missouri."[47] For this reason, I believe Cotter had some responsibility for safe handling of the Latty Avenue wastes from the beginning of operations at the site. Cotter's period of operation constitutes 26.8% of the time waste piles were present at one or the other of the sites (7.5/28 = 0.26.8).

A summary of the allocation analysis is provided below.

	Pre-1966		**1966-1973**		**Post-1973**	
	SLAPS	HISS	SLAPS	HISS	SLAPS	HISS
Ballfields	100%	0%	90%	10%	90%	10%
Latty Ave. Railroad	100%	0%	10%	90%	10%	90%
Latty Ave. Vicinity Sites	100%	0%	10%	90%	10%	90%
Coldwater Creek	100%	0%	73%	27%	73%	27%

[46] Residue Purchase Agreement, June 9, 1967, Exhibit 2 to Volume I of the Deposition of John Stephen Hamrick.

[47] Letter to U.S. Atomic Energy Commission, October 1, 1968, Exhibit 17 to Volume I of the Deposition of John Stephen Hamrick.

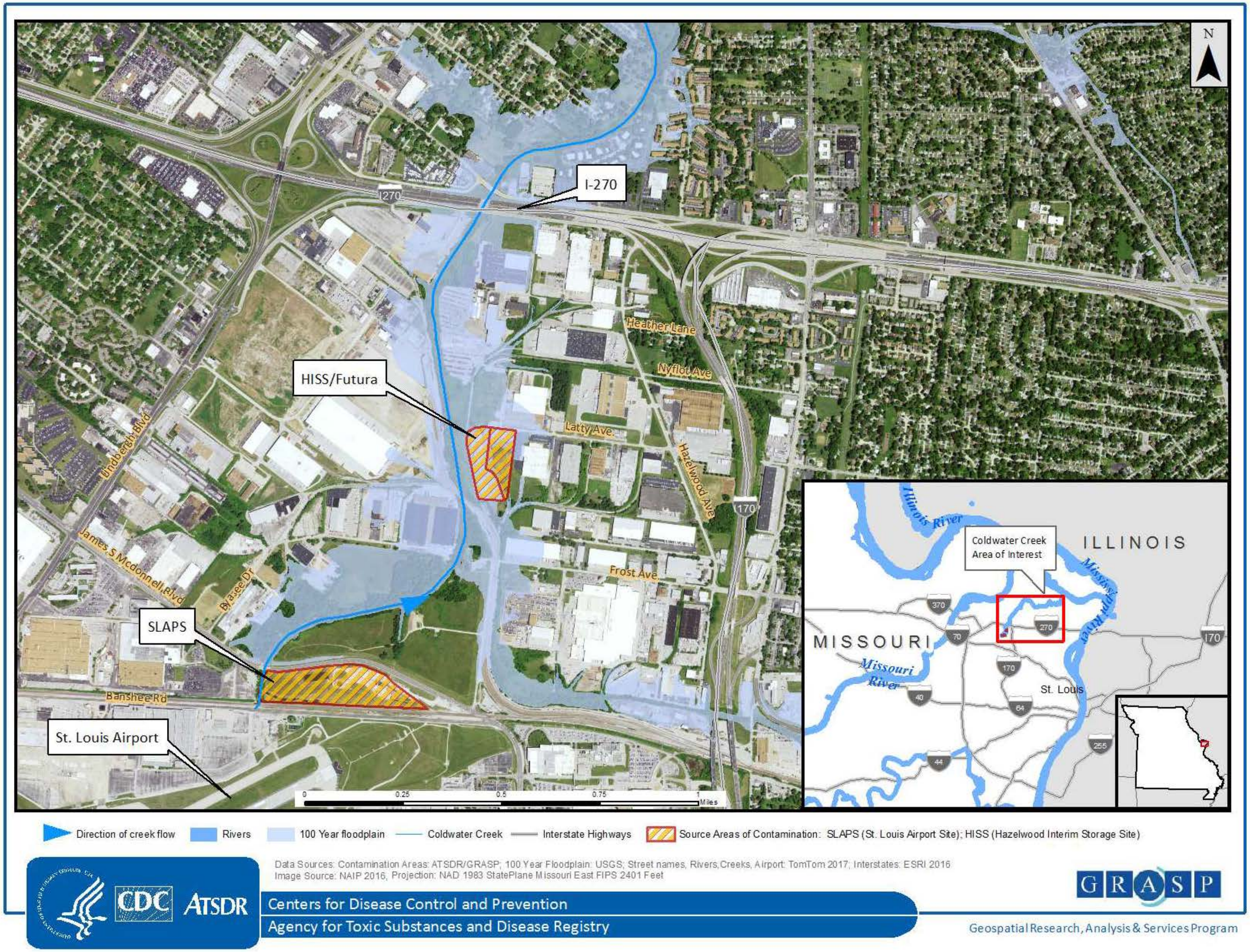

Exhibit 1. Map of a portion of north St. Louis County, Missouri showing SLAPS and HISS (Latty Avenue Site) along with a portion of Coldwater Creek. Source: ATSDR, 2018, Figure 2.

Table 1. Concentrations in Water from SLAPS and Latty Avenue

Radionuclide	Effluent Limitation for Water (uCi/ml)[a]	pCi/ml[b]	pCi/l[c]	Max Conc Reported in Near-Offsite Surface Water (pCi/l)	Source
^{238}U-Soluble	4.0E-05	4.0E+01	40,000	3,500	d
^{230}Th-Soluble	2.0E-06	2.0E+00	2,000	ND (<0.5 - <14)	d
^{226}Ra-Soluble	1.0E-08	1.0E-02	10	0.4	e
^{210}Pb-Soluble	1.0E-07	1.0E-01	100	11	d
^{232}Th-Soluble	2.0E-06	2.0E+00	2,000	9.0	e
^{234}U-Soluble	3.0E-05	3.0E+01	30,000	893.29	f
^{228}Ra-Soluble	3.0E-08	3.0E-02	30	0.51	f
^{228}Th-Soluble	7.0E-06	7.0E+00	7,000	0.93	f
^{235}U-Soluble	3.0E-05	3.0E+01	30,000	0.4	d
^{231}Pa-Soluble	9.0E-07	9.0E-01	900	0.04	f
^{227}Ac-Soluble	2.0E-06	2.0E+00	2,000	0.03	f
Total Uranium	not listed			2,067	e

[a]Source: 10 CFR §20.106(a)

[b]Unit conversion: 10^6 picocuries = 1 microcurie

[c]Unit conversion: 1000 ml = 1L

[d]DOE, 1979, Radiological Survey of the St. Louis Airport Storage Site, Table 19.

[e]Bechtel, 1983, Radiological Survey of Ditches at the St. Louis Airport Storage Site (SLAPS), Table 8.

[f]RAC, 2018, Table 8-3

Table 2. Effluent in Air for SLAPS

	Effluent Limitation for Air[a]							
Radionuclide	**(uCi/ml)**	**(pCi/ml)[b]**	**(pCi/m³)[c]**	Activity Fraction Relative to gross alpha[d]	As a % of ^{238}U	Calculated Activity for 1960 Data (uc/cm³)	pCi/cm³	pCi/m³
^{238}U-Soluble	3.0E-12	3.0E-06	3.0	0.075	100%	2.17E-14	2.2E-08	0.022
^{230}Th-Soluble	8.0E-14	8.0E-08	0.08	0.76	1013%	2.20E-13	2.2E-07	0.220
^{226}Ra-Soluble	1.0E-12	1.0E-06	1.0	0.07	93%	2.03E-14	2.0E-08	0.020
^{210}Pb-Soluble	4.0E-12	4.0E-06	4.0	0.07	93%	2.03E-14	2.0E-08	0.020
^{232}Th-Soluble	1.0E-12	1.0E-06	1.0	0.0054	7.2%	1.56E-15	1.6E-09	0.002
^{234}U-Soluble[e]	2.0E-11	2.0E-05	20.0			2.23E-14	2.2E-08	0.022
^{228}Ra-Soluble	2.0E-12	2.0E-06	2.0	0.015	20%	4.34E-15	4.3E-09	0.004
^{228}Th-Soluble	3.0E-13	3.0E-07	0.30	0.0032	4.3%	9.27E-16	9.3E-10	0.001
^{235}U-Soluble[e]	2.0E-11	2.0E-05	20.0			1.01E-15	1.0E-09	0.001
^{231}Pa-Soluble	4.0E-14	4.0E-08	0.04	0.0035	4.7%	1.01E-15	1.0E-09	0.001
^{227}Ac-Soluble	8.0E-14	8.0E-08	0.08	0.0035	4.7%	1.01E-15	1.0E-09	0.001

[a]Source: 10 CFR §20.106(a)

[b]Unit conversion: 10^6 picocuries = 1 microcurie

[c]Unit conversion: 1,000,000 cm³ = 1m³; 1 ml = 1 cm³

[d]Source: RAC, 2018, Table 4-16

[e]Calculated from natural abundance of uranium isotopes; see text.

Shaded entry exceeds effluent limitation

Table 3. Effluent in Air for Latty Avenue Drying Operation

		Q2 1968	Q3 1968	Q4 1968	Q3 1970	Q4 1970	Q1 1971
PM10 Release from Dryer-AM7[a]	(tons)	2.03	1.92	0.57	1.0	1.62	0.89
PM10 Release from Dryer-AM10[a]	(tons)	0.98	0.95	0.29	0	0	0
% AM7 per qtr		25.3%	23.9%	7.1%	12.5%	20.2%	11.1%
% AM10 per qtr		44.1%	42.8%	13.1%	0.0%	0.0%	0.0%

a) Mass Relea	Total Curies Released from dryer (AM-7)[b]	Total Curies Released from dryer (AM-10)[b]	Q2 1968 emission	Q3 1968 emission	Q4 1968 emission	Q3 1970 emission	Q4 1970 emission	Q1 1971 emission
^{238}U	3.70E-03	1.10E-03	1.42E-03	1.36E-03	4.06E-04	4.61E-04	7.46E-04	4.10E-04
^{230}Th	3.40E-01	9.80E-02	1.29E-01	1.23E-01	3.69E-02	4.23E-02	6.86E-02	3.77E-02
^{226}Ra	2.50E-03	1.20E-03	1.16E-03	1.11E-03	3.34E-04	3.11E-04	5.04E-04	2.77E-04
^{210}Pb[b]	2.50E-03	1.20E-03	1.16E-03	1.11E-03	3.34E-04	3.11E-04	5.04E-04	2.77E-04
^{232}Th	2.40E-05	1.60E-05	1.31E-05	1.26E-05	3.79E-06	2.99E-06	4.84E-06	2.66E-06
^{234}U[c]	3.70E-03	1.10E-03	1.42E-03	1.36E-03	4.06E-04	4.61E-04	7.46E-04	4.10E-04
^{228}Ra[d]	6.80E-06	4.40E-06	3.66E-06	3.51E-06	1.06E-06	8.47E-07	1.37E-06	7.54E-07
^{228}Th[d]	2.10E-05	1.30E-05	1.10E-05	1.06E-05	3.19E-06	2.62E-06	4.24E-06	2.33E-06
^{231}Pa[f]	2.00E-02	7.30E-04	5.38E-03	5.09E-03	1.52E-03	2.49E-03	4.03E-03	2.22E-03
^{227}Ac[f]	2.00E-02	1.40E-03	5.67E-03	5.38E-03	1.60E-03	2.49E-03	4.03E-03	2.22E-03

[a]RAC, 2018, Table 4-33

[b]RAC, 2018, Table 4-34

	Q2 1968	Q3 1968	Q4 1968	Q3 1970	Q4 1970	Q1 1971
PM10 Release from Dryer Operation (tons)	3.01E+00	2.87E+00	8.60E-01	1.00E+00	1.62E+00	8.90E-01
PM10 Release from Dryer Operation (pounds)	6.02E+03	5.74E+03	1.72E+03	2.00E+03	3.24E+03	1.78E+03
PM10 Release from Dryer Operation (mg)	2.73E+08	2.60E+08	7.80E+07	9.07E+07	1.47E+08	8.07E+07

b) Concentrations Released	Effluent Limitation for Air[a] uCi/ml	pCi/ml	pCi/m^3	Conc in air (pCi/m^3)	Conc in air (pCi/m^3)	Conc in air (pCi/m^3)	Conc in air (pCi/m^3)	Conc in air (pCi/m^3)	Conc in air (pCi/m^3)
^{238}U-Soluble	3.0E-12	3.0E-06	3.0	1.6E-02	1.5E-02	4.5E-03	5.1E-03	8.2E-03	4.5E-03
^{230}Th-Soluble	8.0E-14	8.0E-08	0.08	1.4E+00	1.4E+00	4.1E-01	4.6E-01	7.5E-01	4.1E-01
^{226}Ra-Soluble	1.0E-12	1.0E-06	1.0	1.3E-02	1.2E-02	3.7E-03	3.4E-03	5.5E-03	3.0E-03
^{210}Pb-Soluble	4.0E-12	4.0E-06	4.0	1.3E-02	1.2E-02	3.7E-03	3.4E-03	5.5E-03	3.0E-03
^{232}Th-Soluble	1.0E-12	1.0E-06	1.0	1.4E-04	1.4E-04	4.2E-05	3.3E-05	5.3E-05	2.9E-05
^{234}U-Soluble	2.0E-11	2.0E-05	20.0	1.6E-02	1.5E-02	4.5E-03	5.1E-03	8.2E-03	4.5E-03
^{228}Ra-Soluble	2.0E-12	2.0E-06	2.0	4.0E-05	3.9E-05	1.2E-05	9.3E-06	1.5E-05	8.3E-06
^{228}Th-Soluble	3.0E-13	3.0E-07	0.30	1.2E-04	1.2E-04	3.5E-05	2.9E-05	4.7E-05	2.6E-05
^{231}Pa-Soluble	4.0E-14	4.0E-08	0.04	5.9E-02	5.6E-02	1.7E-02	2.7E-02	4.4E-02	2.4E-02
^{227}Ac-Soluble	8.0E-14	8.0E-08	0.08	6.2E-02	5.9E-02	1.8E-02	2.7E-02	4.4E-02	2.4E-02

[a]Source: 10 CFR §20.106(a)

[b]Unit conversion: 10^6 picocuries = 1 microcurie

[c]Unit conversion: 1,000,000 ml = $1m^3$

Unit conversion: $1Ci = 10^{12}$ pCi

Appendix A

Resume of James T. Wells, PhD, PG

L. EVERETT & ASSOCIATES
ENVIRONMENTAL CONSULTANTS

James T. Wells, PhD, PG

Environmental Geologist

L. Everett & Associates, LLC
3700 State Street, Suite 350
Santa Barbara, CA 93105
805-880-9302
jwells@everettassociates.net

Education

University of Washington, Ph.D., Geological Sciences, 1990

University of Washington, M.S., Geological Sciences, 1986

Dartmouth College, B.A., Earth Sciences, 1981

Professional Registration

2001/California: Professional Geologist (Reg. No. 7212)

Professional Societies

Geological Society of America

American Ground Water Association

American Chemical Society

International Society of Environmental Forensics

Dr. Wells is an environmental geologist with over 25 years of experience in hydrogeology and geochemistry and is a Professional Geologist, registered in California. His area of expertise includes groundwater hydrology, fate and transport of contamination in soil and groundwater, environmental forensics and the geochemistry of metals in the environment. He is a member of the Editorial Board of the journal, Environmental Forensics, a quarterly peer-reviewed scientific journal of national and international circulation. He is the author and coauthor of numerous scientific publications, including the recently published forensic review articles in Environmental Science & Technology (U.K. Edition) Special Issue dedicated to Environmental Forensics.

Dr. Wells has worked on over 100 sites around the country, each with unique issues related to soil or groundwater quality. He serves clients in the areas of site investigations, soil and groundwater remediation, risk-based studies of soil and groundwater contamination, and litigation support. Dr. Wells has managed complex environmental programs on behalf of large corporations. His environmental forensics practice focuses on using advanced analytical techniques to solve questions related to the origin, cause, timing and evolution of subsurface contamination. He has extensive experience in groundwater and vadose zone computer modeling, as well as in the statistical analysis of geological systems. L. Everett & Associates' billing rate for Dr. Wells is $275/hr. His hourly rate for deposition and trial testimony is $500/hr.

Representative Project Experience

Former Sylvania Site – Hicksville, New York.
Conducted assessment of site investigation and remediation at FUSRAP (Formally Utilized Sites Remedial Action Program) site on Long Island. This facility was an early supplier of nuclear fuel elements for the nation's first commercial reactors. Soil and groundwater contamination included uranium, thorium, nickel and organic solvents.

Gallagher & Kennedy – Litigation Support. Provided litigation support for a lawsuit involving a 996-acre brownfield site. The site, used since the 1930s for munitions manufacturing and assembly, had soil and groundwater contamination consisting of perchlorate, chlorinated solvents and radioactive materials. When the local municipality took 13 acres of the property by eminent domain to build a new regional highway, the property owner sued to recoup the cost of the land. The municipality estimated a cleanup cost of $220 million and, based on this, valued the land at only $142,000. With colleagues, developed a soil and groundwater remediation plan and cost estimate. Through extensive soil and groundwater data analysis and 3D modeling, demonstrated that while portions of the site were highly contaminated, much of the site was not contaminated and a

lower cost remediation was feasible. Our remediation plan dovetailed remediation with pre-development activities and employed state-of-the-art remediation technologies for perchlorate at a cost $27 million. A jury accepted the accuracy of Haley & Aldrich's remediation estimate, and awarded the owner over $12 million for land value and severance damages.

University of Washington Advisory Group on Hanford Site. Served as graduate student representative to technical advisory group providing advice to State officials in their oversight role for the environmental cleanup at Hanford in eastern Washington State.

SIMA Property Corporation – Chlorinated Solvent Site in California. Conducted site characterization, remediation planning, regulatory negotiation for PCE in soil, soil vapor and groundwater at this dry cleaner site, with special emphasis on the potential for vapor intrusion into nearby commercial buildings.

Applies expertise in geo-chemistry and hydrogeology to solve environmental problems

Rand Family Trust – Petroleum hydrocarbons in soil and groundwater. Conducted site characterization and site remediation for a commercial site in Santa Barbara, California. Achieved closure of this case from the local regulatory agency.

Reedley Remediation Trust – Chlorinated Solvent Site in California. Provided site characterization and remediation planning advice for this comingled PCE groundwater plume. Also advised on the formation of a remediation trust to insure adequate resources for a long-term cleanup program.

Isola Law Group – Rialto-Colton Superfund Site. Provided litigation support in complex, multi-party lawsuit concerning cost allocation, contaminant fate and transport and remediation technologies for large (5-mile long) perchlorate and TCE groundwater plume.

KB Gardena – Litigation Support & Subsurface Remediation. Provided attorneys with technical advice and assistance with cost allocation strategy for multi-million dollar case with multiple PRPs. Conducted site remediation for PCE, metals and other VOCs.

Pacific Gas & Electric Company – Forensic Geochemistry. Analyzed high-resolution petroleum hydrocarbon data, including PIANO analysis, relative solubility and hydrocarbon weathering assessments to evaluate the theory that contamination discovered on client's property originated from off-site sources and was not due to on-site releases. PIANO analysis is a forensic technique for complex hydrocarbon mixtures using gas chromatography to speciate individual hydrocarbon compounds and group the compounds into their molecular classifications: paraffins (P), isoparaffins (I), aromatics (A), naphthalenes (N) and olefins (O).

Pacific Gas & Electric Company – Litigation Support. Provided litigation support, including participation in mediation, for a case involving petroleum

hydrocarbons in soil and groundwater.

USEPA – Del Amo and Montrose Superfund Sites. Analysis of potential exposure scenarios and efficacy of remediation plans from PCBs, metals and VOCs from Superfund sites in Los Angeles under EPA's TASC program (Technical Assistance Services for Communities).

Terracon, Inc. – Groundwater Modeling and Litigation Support. Complex construction defect case involving claims of $60 million in damage allegedly due to soil expansion caused by rising groundwater from irrigation of nearby golf course and residential areas. Opposing experts spent two years and $2 million on groundwater modeling which was eventually excluded from trial after we demonstrated unreliability and lack of relevance to judge.

His area of expertise includes environmental forensics and fate and transport of organic and inorganic contaminants in soil and groundwater

St. Joe, Missouri—Chromium in Tannery Waste. Provided litigation support for case in which tannery waste had been spread as soil amendment over approximately 56,000 acres of agricultural land. It had been known that the sludge contained elevated levels of metals, including chromium. It was apparently not known that some of the chromium was in the form of toxic Cr(VI) which posed a serious risk to human health and the environment.

State of Idaho – Soil Remediation Pilot Study for Metal Stabilization on the Coeur d'Alene Mining District. Conducted field pilot study on metal stabilization along the Coeur d'Alene River. The river feeds Lake Coeur d'Alene which is highly-impacted by the cumulative effects of 100 years of mining in the watershed and is the primary source of drinking water for over 50,000 residents of northern Idaho. Work was sponsored by the U.S. Environmental Protection Agency (EPA) and State of Idaho in an effort to find a cost-effective means of addressing widespread soil contamination along a 30 mile stretch of the Coeur d'Alene River.

Confidential Client – Environmental Forensics for Metals. Conducted forensic analysis of groundwater contamination allegedly emanating from a mining operation. The project involved fate and transport evaluations, groundwater hydrogeology, and geochemistry.

Litigation Support – Metals Contamination
Provided litigation support in case involving alleged lead and arsenic soil contamination due to pesticides.

Koch Oil, Oklahoma – Forensic Geochemistry. Conducted forensic geochemical evaluation on naturally-occurring compounds in groundwater to assess whether historical groundwater concentration trends constituted natural background variability or potential releases from client's brine impoundments.

Tri-County Public Airport, Herington, Kansas – Forensic Geochemistry. Conducted oxygen, deuterium, chlorofluorocarbon (CFC), carbon isotope analysis of groundwater and chlorinated contaminants in order of evaluate contaminant fate and transport at a former military facility.

Gonzalez & Robinson – Groundwater Modeling. Used groundwater computer modeling to simulate groundwater flow in a residential region of Sonoma County, California.

Confidential Client – Environmental Forensics for Chlorinated Solvents. Conducted forensic analysis of chlorinated solvent contamination extending in groundwater over two miles under a community. The site involved multiple releases from multiple locations and complex hydrogeology and attenuation histories.

Kimberly-Clark, Ohio – Forensic Geochemistry. Conducted forensic geochemical analysis to demonstrate that significant component of groundwater contamination under client's site had migrated from an off-site source. Utilized compound-specific carbon isotope analysis of chlorinated compounds and daughter product abundance. This analysis was complicated by the fact that there were low levels of residual contamination from an old on-site release, which needed to be definitively differentiated from the larger off-site flux of contaminants.

Western States Petroleum Association – Risk-Based Clean-up Studies. Conducted a study to develop risk-based clean-up standards for crude-oil-impacted soils, including studies of the comparative environmental risks posed by crude oil, gasoline, and diesel oil in the subsurface. Applied leaking underground fuel tank evaluation methods to crude oil sites and developed cost-effective site assessment strategies.

Tesoro Petroleum Company – San Fernando Investigation and Remediation of MTBE Plume. Managed a project in Southern California to delineate and clean-up a large release of methyl tert-butyl ether (MTBE) to soil and groundwater. A particular challenge of this project was to account for the presence of multiple high-volume water supply wells near the project site, a situation involving extensive regulatory negotiation with California Regional Water Quality Control Board (RWQCB), California Department of Health Services and Upper Los Angeles River Area Watermaster.

Isola Bowers, LLP – Environmental Litigation Support. Served as expert witness in a case involving a large release of MTBE-bearing gasoline to groundwater. Estimated volume of release and reconstructed release and plume migration history.

ContiGroup Companies, Stockton, CA – Groundwater Remediation. Completed comprehensive subsurface characterization study and designed a remediation strategy for this grain elevator site with carbon tetrachloride and other volatile organic compounds in groundwater. Due to the complex stratigraphy and heterogeneous distribution of contaminant throughout the aquifer, an in-situ chemical treatment strategy was designed for this site coupled with an initial, short-term phase of groundwater extraction to achieve containment of the contaminant plume.

Confidential Client - Aircraft Manufacturer – Service Delivery Leader. Served as Service Delivery Leader, responsible for coordinating quality and consistency for a team located in six offices and providing environmental services simultaneously on up to ten large projects. Also conducted vadose zone computer modeling to evaluate clean-up standards for soil that would be protective of future groundwater quality.

Northrop-Grumman Corporation—Remediation Planning. Provided analysis of environmental data and regulatory requirements for large site with multiple occurrences of contamination in soil and groundwater. Advised client on cost-effective strategies and technologies for resolving environmental impairment.

Archbald & Spray, LLP – Environmental Litigation Support. Served as expert witness on environmental issues for the case, Exxon v. Ebasco. In this case, environmental issues included storm water management, erosion control, hazardous waste handling, water quality and regulatory compliance during construction of a large petroleum processing facility in Santa Barbara County, California.

Price, Postel & Parma, LLP – Environmental Litigation Support. Provided environmental review and interpretation in support of legal cases. Served as expert witness on cases involving groundwater contamination and aquifer remediation.

Tesoro Petroleum Company – Feasibility Study for Remediation of Free Product. Conducted a feasibility study for containment and remediation of a large plume of free phase petroleum plume at a refinery in Kenai, Alaska. Migration of the light non-aqueous phase liquid was influenced by complex fluvio-glacial stratigraphy and by fluctuating groundwater levels.

Exxon Company, U.S.A. – Remediation Planning. Developed remediation and regulatory strategies for the closure of a large urban oil field in California, which consists of over 500 production sites over four square miles of residential and commercial districts. The proposed strategy was a risk-based approach addressing such factors as cost, schedule, future liability and land use.

Confidential Client - Aircraft Manufacturing Site Redevelopment Environmental Program. Team member for comprehensive subsurface investigation program for 343-acre former manufacturing facility. This complex project involved over 1500 soil borings, web-based data repository, risk-based formulation of clean-up standards, production of data reports specifically designed for use by potential buyers and other stakeholders and close coordination with redevelopment staff.

Nestlé, U.S.A. –Aquifer Remediation. Working with Nestlé technical staff, developed a technical strategy and gained regulatory acceptance of a passive bioremediation approach at an underground storage tank (UST) site which

contained hydrocarbon contamination in groundwater in a beneficial-use aquifer.

San Diego County Aquifer Storage and Recovery. Served as technical advisor on project evaluating the feasibility of aquifer storage and recovery operation in central San Diego County, California. Project involved extensive groundwater modeling, evaluation of climate variability and evaluations of geochemical compatibility of various potential sources of water with native groundwater and aquifer matrix.

County of San Luis Obispo Water Supply – Nitrate in Groundwater. Conducted a study of nitrate contamination in shallow groundwater at Los Osos, California, a community that relies solely on groundwater for its municipal water supply. The study incorporated site-specific data on the transport and transformation of nitrogen in the subsurface to develop a nitrogen mass balance for all significant nitrate sources. This work resulted in quantitative estimates of the contribution of septic system effluent to nitrate levels in groundwater.

U.S. Navy – Groundwater Investigations and Remediation Planning. Managed site investigations, feasibility studies and remediation planning at eight contaminated sites overlying (and in some cases, impacting) the sole-source aquifer at Camp Pendleton Marine Corps Base.

Santa Barbara Historical Society – Environmental Consulting. Provided environmental consulting services, advice, reviews of reports and data and participated in negotiations with Southern California Edison (the responsible party) on behalf a Santa Barbara nonprofit organization. This work focused on soil and groundwater investigations, remediation plans and associated risks related to soil and groundwater contamination at a former manufactured gas plant on the nonprofit's property.

Sequoia Voting Systems – Groundwater Investigations. Managed a project involving chlorinated compounds in groundwater in which I developed supporting data and argued for relief from active remediation on the grounds of the existence of natural contaminant of the chlorinated plume. Our approach was approved by the state.

Los Angeles Metropolitan Transportation Authority (LACMTA)– Comprehensive Environmental Services. Project manager for comprehensive hazardous waste assessment contract with the LACMTA. For this project, M&E provided environmental services in support of land acquisition and construction for a light-rail commuter line in the Los Angeles area.

Private Client – Vadose Zone Studies. Performed detailed vadose zone investigations in support of landfill siting projects which involved geophysical surveys and soil testing to assess the nature and distribution of soil moisture and to assess the potential for contaminant migration in the vadose zone.

State of California – Soil and Groundwater Remediation. Implemented an air sparging/soil vapor extraction soil and groundwater remediation system at a UST

site with extensive vadose zone and dissolved groundwater plumes.

U.S. Air Force – Risk-based Strategies for Soil. Utilized the California RWQCB Designated Level Methodology to establish clean-up levels for soil contaminated with petroleum hydrocarbons at Beale Air Force Base, California. This project involved vadose zone contaminant transport computer modeling to arrive at soil clean-up levels that would produce acceptable predicted impacts to underlying groundwater.

Various Clients – Geostatistical Programs. Developed programs for the statistical analysis of groundwater monitoring data for a mining facility, petroleum refinery, wastewater reclamation operation and a municipal waste landfill, all in Central California. Projects involved the implementation of EPA-approved statistical techniques to evaluate the differences between background and downgradient concentrations of groundwater contaminants.

Depositions and Trial Testimony

2018, Renzel v. Ventura, Deposition Testimony.

2018, Weiand Automotive Industries, Inc. et al., Deposition Testimony.

2017, Greenfield MHP Associates, L.P., et al.vs. Ametek, Deposition Testimony.

2017, Wyatt, et al., vs. ABB, Inc., Deposition Testimony.

2016, Kirk vs. Schaeffler, Deposition and Trial Testimony.

2016, Goldberg vs. Goss-Jewett, et al., Deposition Testimony.

2015, Hawkins, et al., vs. Vista Ridge Development Corp., et al., Deposition Testimony.

2013, Enns Pontiac, et al., vs. Flores, et al., Deposition Testimony.

2012, Steadfast, et al., vs. Terracon, et al., District Court of Jefferson County, Colorado, Deposition and pre-trial Hearing Testimony.

2012, Kartal vs. Chang, et al., Deposition Testimony.

2011, Johnson, et al., vs. Prime Tanning Corp., et al., Circuit Court of Buchanan County, Missouri, Deposition Testimony.

2010, United Alloys vs. Flask, United States District Court, Central District of California, Deposition and Trial Testimony.

2010, Acevedo, et al., vs. California Spray Chemical Company, et al., Superior Court of the State of California, County of Santa Cruz, Deposition .

2009, ITT vs. BorgWarner, et al., United States District Court for the Western

District of Michigan, Deposition and Trial Testimony.

2009, DePascale. Et al., vs. Sylvania, United States District Court for the Eastern District of New York, Deposition and Trial Testimony.

2009, Clark, et al. vs. City of Santa Rosa, et al., Superior Court of the State of California, County of Sonoma, Deposition and Trial Testimony.

2008, Hinds Investments, L.P., et al. vs. United Fabricare Supply, Inc., et al., Deposition, Los Angeles, California, Deposition.

2008, Acevedo, et al., vs. California Spray Chemical Company, et al., Superior Court of the State of California, County of Santa Cruz, Deposition and Trial Testimony

2005, City of Santa Clarita vs. Santa Clarita, LLC, et al., Superior Court of the State of California, County of Los Angeles, Deposition.

2003, City of Morgan Hill, Santa Clara County, California, Deposition and Trial.

1999, Unocal vs. Terrible Herbst, Las Vegas, Nevada, Deposition and Trial Testimony.

1998, Exxon v. Ebasco, Santa Barbara County, California, Deposition.

Publications and Papers

Expert Witness Services for Environmental Scientists and Engineers: Professional Opportunities at The Intersection of Law and Science, in: *Applied Geology of California*, Anderson and Ferriz, eds., Chapter 29 (with Schaal, Matos and Everett).

"Emerging Trends in Environmental Forensics," presentation and paper for American Law Institute Conference on Environmental Litigation, Washington, DC, 2013.

"Tracking Chlorinated Solvents in Nature – Classic and Emerging Forensic Techniques", with I. G. Petrisor, in *Environmental Forensic*s, Volume 26 in the Issues in Environmental Science and Technology series, 2008.

"Perchlorate: Is Nature the Main Manufacturer?", with I. G. Petrisor, in *Environmental Forensics*, Volume 26 in the Issues in Environmental Science and Technology series, 2008.

"Environmental Forensics," presentation to the AIHA Joint Symposium, Long Beach, California, 2004.

"A Lattice Gas Model for Heterogeneous Chemical Reactions at Mineral Surfaces and in Pore Networks," with D.R. Janecky, and B. Travis, *Physica D, vol. 47, pp. 115-123,* 1991.

"Coupled Fluid Flow and Chemical Reactions in Mid-Ocean Ridge Hydrothermal

Systems: The Behavior of Silica," with M.S. Ghiorso, *Geochimica et Cosmochimica Acta, vol. 55, pp. 2467-2482,* 1991.

"The Influence of Fluid Flow and Reaction Kinetics on Mass Transfer in Mid-Ocean Ridge Hydrothermal Systems." Dissertation, University of Washington, 1990.

"3-D Numerical Models for Examining Processes in Geothermal-Hydrochemical Systems," with D.R. Janecky, B.J. Travis, G. Zyvloski, N. Rosenberg. Chapman Conference on Crustal-Scale Fluid Transport, Snowbird, Utah, 1990.
"Cellular Automata Simulations of Mineral Surface Reactions," with D.R. Janecky, and B. Travis, Geological Society of America Annual Meeting, St. Louis, 1989.

"Determining Fluid Velocity of Black Smoker Jets from Digital Correlation of Video Images," with M.O. Smith, V.A. Atnipp, and R.E. McDuff, American Geophysical Union Fall Meeting, San Francisco, 1989.